RENEW THE PARKS

Renewable Energy in the National Park Service

Photovoltaic Systems

PHOTOVOLTAIC DESIGN ASSISTANCE CENTER · SANDIA ·

NATIONAL PARK SERVICE

RENEWABLE ENERGY IN THE NATIONAL PARK SERVICE

INTRODUCTION

The National Park Service is the steward of some of the world's finest natural and cultural resources and is regarded by many people as the premier resource conservation agency in the United States if not the world. The mission of the National Park Service is clearly defined in the organic act of 1916.

> *to conserve the scenery and the natural and historic objects and the wildlife therein, and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.*

This strong mandate and policy direction has always emphasized protecting and conserving this country's cultural and natural resources while providing the visiting public with opportunities to learn about these resources. When the National Park Service celebrated its 75th anniversary in 1991, it charted a course for how it would accomplish its mission into the next century. The resulting vision document titled *National Parks for the 21st Century: The Vail Agenda*, provides strategic objectives and directions for the future management of the National Park Service. Incorporating sustainability and sustainable design was recommended in *The Vail Agenda* as one method of meeting challenges that currently face the National Park Service.

The Park Service defines sustainable design as a design that meets the needs of the present without compromising the ability of future generations to meet their own needs. Many people feel this definition bears a striking resemblance to the organic act — the founding legislation for the National Park Service.

Sustainability and sustainable design also have received commitment from the administration as evidenced by the establishment of the President's Council on Sustainable Development, the signing of the Climate Change Action Plan, the implementation of Executive Order 12902 ("Energy Efficiency and Water Conservation at Federal Facilities"), and the establishment of Technology for a Sustainable Future.

An important part of the recently approved NPS *Strategic Plan* is to achieve sustainability in all national park operations and development. In October 1992 the National Park Service released *Guiding Principles of Sustainable Design* to provide a framework for achieving sustainability in all activities.

One of the main components of sustainable design is energy management. The use of renewable energy sources, such as photovoltaics (PV), is a key strategy for energy management. In fall 1992 the Denver Service Center of the National Park Service contacted the Photovoltaic Design Assistance Center (PVDAC) at Sandia National Laboratories in Albuquerque, New Mexico, to provide technical training to interested NPS professionals. As a result of this initial session, a partnership was developed to promote energy conservation and increase the use of renewable energy at NPS facilities. An equally important objective was to provide educational opportunities to park visitors in the specific areas of energy conservation, renewable energy, and sustainability in general. In fall 1993 a partnership agreement was funded by the Photovoltaic Design Assistance Center to survey all national park system units to

- locate existing PV systems and determine their function
- assess the satisfaction with existing PV systems
- identify potential future PV projects
- identify barriers to the use of PV power and propose solutions

METHODOLOGY

In February 1994 NPS Deputy Director John Reynolds transmitted to each national park system field unit a survey questionnaire concerning existing PV use and other sustainable practices, the potential for future PV use, and barriers to that potential use. A sample survey questionnaire is included as appendix A. There are 368 field units, which include national parks, national monuments, national historic sites, national seashores, national recreation areas, etc. These field units will hereafter be referred to in aggregate as parks. However, a particular management unit might manage multiple field units. It is

estimated that for the 368 field units surveyed, 278 management units exist; 201 management units responded to the survey.

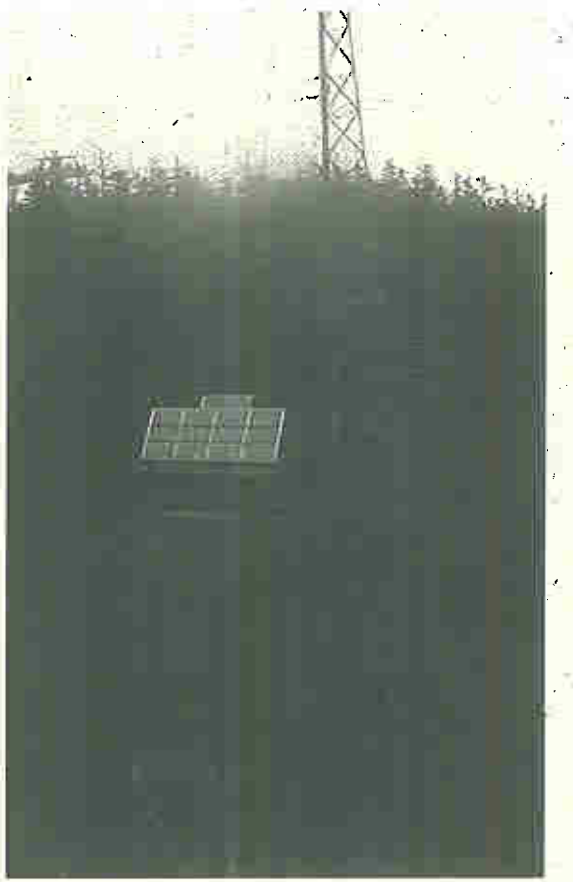
Information from the surveys was used to create a database and forms the foundation for this report. Information in the database concerning existing PV systems will be integrated into the National Park Service's Inventory and Condition Assessment Program (ICAP) once that program is deployed servicewide. The Denver Service Center will continue to update and maintain the listing for future PV projects.

Follow-up phase II surveys were sent to those parks that identified potential PV projects of a larger scale. The purpose of the phase II surveys was to roughly determine the size of potential PV projects so that a cost estimate for programming could be prepared by the Denver Service Center. The goal of this data collection and cost estimating effort is to formulate a five-year program to expand the use of renewable energy in the parks. Under this new program called "Renew the Parks," park personnel will be trained on renewable energy and the creation of partnerships will be encouraged.

EXISTING PHOTOVOLTAIC USE IN THE NATIONAL PARK SERVICE

According to the survey there are at least 455 existing PV systems in use today. Based on subsequent visits to parks, there is a likelihood that not all small PV systems were accurately included in the survey responses. It is estimated that more than 600 PV systems are currently in use in the Park Service. Appendix B contains a listing of all the reported PV systems currently in use.

The use of PV systems by the National Park Service is occurring over a broad geographical area and in many climatic conditions. Historically, PV energy was first used in communication systems at remote locations, such as radio repeater sites on mountaintops. Later PV energy was found to be effective in supplying power for resource monitoring equipment. Most recently PV systems have been used to meet larger power needs such as water pumping, remote facility power, and indoor/outdoor lighting. Using PV energy for ventilation at



Typical use of photovoltaic energy to power a radio repeater for Park Service radio communications, Great Smoky Mountains National Park

campground restrooms, composting toilets, and vault toilets also is a significant use.

One exception to this historical progression is the PV system at Natural Bridges National Monument. At the time of installation by the National Park Service and the Department of Energy in 1980, this 100kW system was the largest stand-alone system in the United States. This system provided reliable operation, meeting the electrical loads of the visitor center and ranger residences until 1989 when the useful life of the batteries ended. In 1992 the batteries were replaced, and the system returned to service as a PV hybrid, providing a clean and noiseless source of power that is compatible with the sustainable operation of the park.

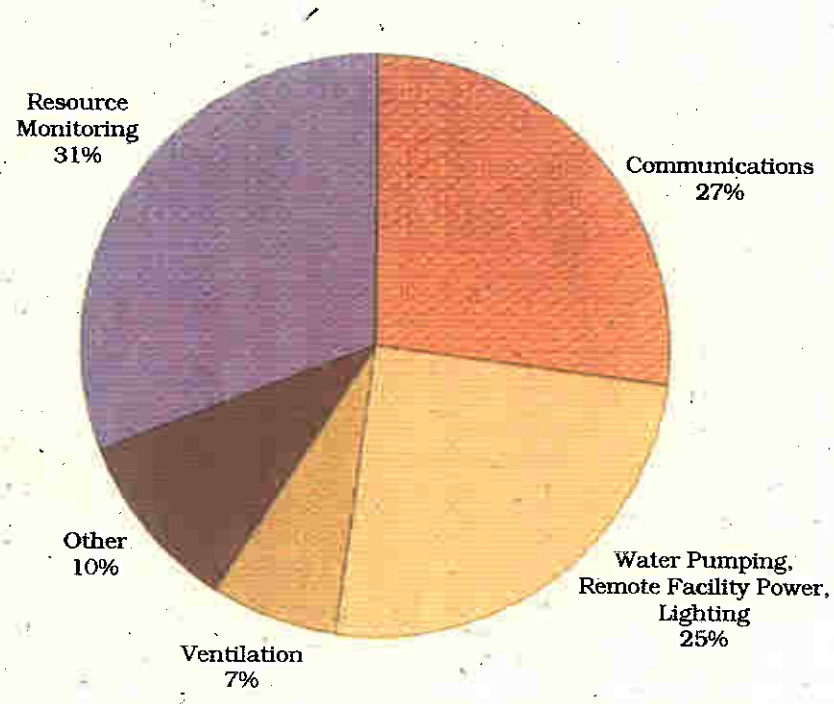


Figure 1: Distribution of Existing PV Uses in the National Park Service

The majority (61%) of the existing PV systems are used on a year-round basis; 34% are used seasonally, and the remaining systems (5%) have intermittent applications or have been abandoned. The ages of existing PV systems are listed below.

- 23% less than two years
- 28% two to less than five years
- 34% five to less than 10 years
- 15% 10 years or more

A majority of the power demands are less than 1 kilowatt (kW).

Remote monitoring is a very powerful tool in natural resource protection and management. Seismic, water level, water flow, snow depth, atmospheric conditions, and wildlife observations are some of the applications where PV energy is used.

. . . 97% of the existing PV systems met their use objectives.

Using PV power to pump water is an especially attractive option at NPS facilities. Photographs on the following pages depict some of these PV applications.

EVALUATION OF EXISTING PHOTOVOLTAIC SYSTEMS

As part of the survey, parks with existing PV systems were asked to evaluate each component of the PV system and the system as a whole (see appendix A).

Responses indicated that 97% of the existing PV systems met their use objectives. Problems associated with the remaining systems (3%) included

- operating errors (turning system off in winter)
- poor design (insufficient charging capacity and/or battery storage)
- component failure
- photovoltaic panels stolen and/or vandalized

At Everglades National Park, a 10-watt PV panel is used to power remote hydrologic monitoring equipment. The monitoring equipment shown measures water depth on an hourly basis and downloads the daily record to a central NPS research facility.

Only two cases of vandalism were reported; however, five cases of theft were reported. Theft of PV panels is a growing problem, especially at remote locations. As the monetary value of PV panels becomes increasingly known, theft is expected to increase unless mitigating measures are implemented. Measures may include carefully selecting locations at unsupervised sites and using vandal-resistant connectors and fasteners.

In addition to the 3% of PV systems that failed to meet their use objective(s), respondents indicated that another 3% of the PV systems evaluated performed poorly in one or more component areas. Even though these PV systems experienced component problems, the parks surveyed felt the use objectives for these slightly flawed systems were being met.

Component problems identified by the parks included battery problems (19 systems), PV panel problems (10 systems), and controller problems (eight systems).

There was no correlation between the age of the troubled systems and problems they were experiencing. It was originally thought that older systems would exhibit more problems; however, most of the problem systems were evenly distributed between the two- to four-year category and the five- to nine-year category. It should be noted that only three systems less than two years old were reported to have any problems.

Survey results concerning estimated annual operations and maintenance (O&M) costs for PV systems were broken into three categories: less than expected or no O&M costs (39%), expected O&M costs (60%), and greater than expected O&M costs (1%).

BARRIERS

Of the 201 PV survey responses received, 151 identified at least one barrier for using a PV system. Most respondents identified multiple barriers. Parks without existing PV systems had more concerns (38%) than those parks with existing PV systems.

The perceived barriers to the use of photovoltaic power are shown in figure 2.

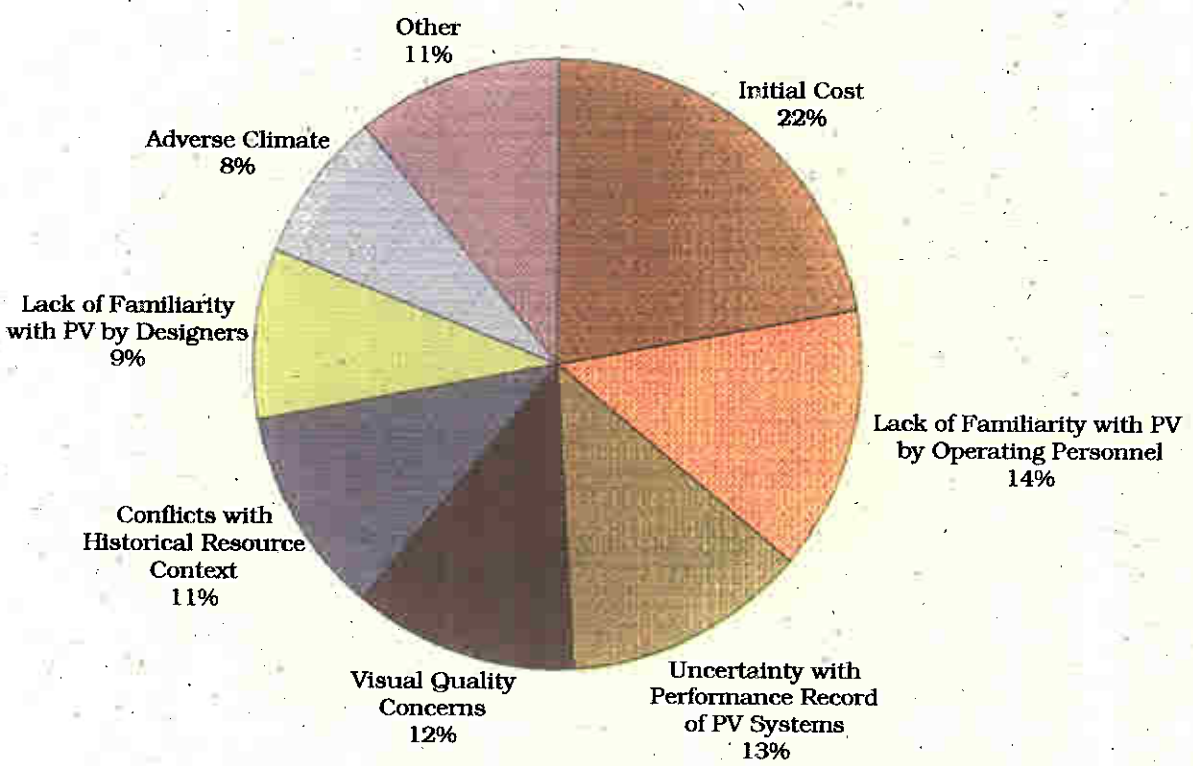


Figure 2: Barriers to the Use of Photovoltaic Power

Initial Cost

According to the survey, the initial cost of PV systems was the biggest concern. To overcome this barrier, the National Park Service will have to form partnerships with other agencies and groups. Potential partners include the Department of Energy, Sandia National Laboratories, the National Renewable Energy Laboratory, the Environmental Protection Agency, environmental groups, and the PV industry. The Department of Energy's Federal Energy Management Program has been established to

On the remote north rim of the Black Canyon of the Gunnison, photovoltaics is the primary power source for a combination visitor contact station and ranger residence. Note how the PV system has been integrated into the site to enhance visual quality.

fund viable energy and water conservation projects as well as renewable energy projects undertaken by federal agencies. The National Park Service brings to any potential partnership 75 years of environmental education experience and the opportunity to promote energy innovation and education to the 270 million visitors that come to the parks each year.

To reflect all the impacts (including costs) of using fossil fuels to generate electricity, and in support of the Climate Change Action Plan, the Park Service is interested in improving air quality by eliminating emissions associated with the burning of fossil fuels. The following emission costs are used as part of life-cycle costing for every NPS development decision:

- carbon dioxide (CO_2 $8 / ton
- sulfur dioxide (SO_2) $0.75 / pound
- nitrous oxide (NO_x) $3.40 / pound

For complete information on quantifying environmental emissions and applying the cost factors see appendix D.

Lack of Familiarity with PV by Operating Personnel and Uncertainty with the Performance Record of PV Systems

These two barrier items are similar in many respects. Common methods in achieving technology transfer can be applied here. Technical presentations at national, regional, and park conferences and meetings are an effective way to introduce PV technology in a general format. Sandia's Photovoltaic Design Assistance Center and the National Renewable Energy Laboratory can provide excellent overview presentations. These overview presentations need to feature park areas that are currently using PV energy. Personnel from the following areas have had good operating experiences with larger PV applications (remote facility power and water pumping) and are important in communicating the performance record of PV systems to their NPS colleagues.

Channel Islands	Natural Bridges	Rocky Mountain
Sleeping Bear Dunes	Glen Canyon	Great Basin
Death Valley	Capitol Reef	Yosemite
Black Canyon of the Gunnison	Crater Lake	Wrangell-St.Elias

Technical training is required to provide a fundamental technical foundation for design and O&M personnel. This formal training can be provided by a number of outside sources. Photovoltaic site assessments provide site-specific recommendations concerning system feasibility. Communications between NPS users and O&M personnel regarding PV power is also promoted in photovoltaic site assessments. Sandia's Photovoltaic Design Assistance Center has provided outstanding service in this area.

One final barrier that must be overcome in this category is the association of PV performance with the performance of early solar thermal for hot water heating. In the late 1970s and early 1980s the National Park Service undertook an initiative to expand the use of solar thermal for domestic hot water heating. This initiative was very similar to the current renewable energy initiative with hopefully one exception — results. Many of the solar hot water systems installed during this time are no longer functional and have been removed or disconnected and left on rooftops as a testament to an unsuccessful solar thermal program.

It is paramount that PV systems deliver the results promised on a sustained basis. Some field personnel are very skeptical of renewable energy based on this past experience with solar thermal.

Photovoltaic power is used on a large scale at Channel Islands National Park to provide electricity at several sites. On Santa Barbara Island, a 5 kW system provides power to a new building that contains a visitor contact station, maintenance shop, and residence.

This PV powered water pumping system at Sleeping Bear Dunes National Lakeshore provides several hundred gallons per day at system pressures of 20–40 psi. Because this is a pressure tank system, batteries are required to provide 24-hour water

This water pumping system at Capitol Reef National Park meets the peak season demand of 20,000 gallons per day at a total dynamic head of 35 feet. This system uses gravity water storage tanks, which eliminates the need for electrical battery storage. The system is further enhanced by the use of low-flow plumbing fixtures at facilities, which have significantly reduced the total volume of pumped water.

Visual Quality Concerns and Conflicts with Historic Resources

These two barriers are significant because they impact the basic management objectives of the National Park Service — "to leave them [cultural and natural resources] unimpaired for the enjoyment of future generations."

To overcome these barriers, several action plans are offered. Small PV systems associated with smaller electrical loads will have very little impact on visual quality. The installation of large PV systems in developed areas will have a visible impact. This impact needs to be viewed as an opportunity to interpret the use of renewable energy and the positive impacts this use has on the global environment. The National Park Service has a mandate as well as a tremendous opportunity to educate the 270 million visitors that enter the parks each year on the use of sustainable technologies such as renewable energy.

For large PV systems in the more sensitive developed areas, the Park Service has the capability, at the Denver Service Center, to use computer visual simulation to show how the developed area would look after the proposed PV system has been constructed. The process involved to achieve this depiction is to initially design (size) the PV system, obtain a real-time photograph of the developed area from a critical viewpoint, and superimpose, to scale, the PV system on the site photograph. This technique enables siting modifications to be enacted and provides park management with a clear perspective of what the completed facility would look like.

Not all PV systems need to be constructed on or near existing facilities; however, there are certain technical advantages in having the PV systems near the power use point. Photovoltaic systems can be located away from critical areas to reduce visual impacts and/or take advantage of increased exposure to the sun. Depending on the voltage used, the balance of system (BOS) components such as batteries, charge controllers, inverters, etc., may also have to be remotely located. Large PV systems may also be split into several smaller systems to mitigate visual quality concerns.

FUTURE USE OF PHOTOVOLTAIC POWER

As part of the survey, parks were requested to indicate proposed PV projects (see appendix A). It was anticipated that parks would identify about 100–150 future PV projects. After all the data was compiled, 643 future PV projects were identified by 125 parks. The breakdown by use category is shown in figure 3.

Figure 3 indicates that the percentage of proposed use anticipated for remote facility power (water pumping and lighting) is increasing compared to the historical big users of PV power (communication and resource monitoring). Remote facility power requires larger PV systems than communications and resource monitoring. The implication may be

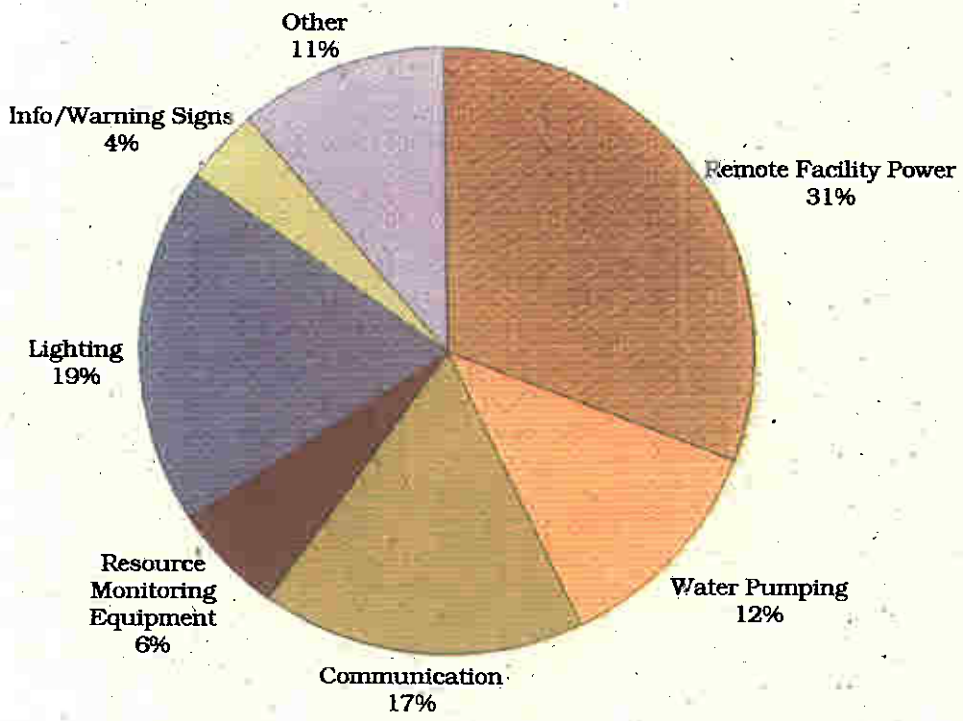


Figure 3: Future Use of Photovoltaic Power in the National Park Service

that PV users are becoming accustomed to this technology and want to move up to the next level.

Appendix C lists all the proposed PV projects by application and location and are compiled in a five-year action plan. Total cost of the 643 projects listed is estimated at $28 million. The survey identified current uses and potential future projects. More than a megawatt of new, cost-effective applications for photovoltaic energy are shown in appendix C, which represents only a fraction of the potential uses identified so far. Cost estimates for each application were prepared by the Denver Service Center and include not only direct PV construction costs but costs for implementing demand side management strategies such as converting to propane heating, installing energy efficient appliances and lighting, and converting to water-conserving plumbing fixtures (the National Park Service has the drinking water and wastewater utility at most locations).

. . . 643 future PV projects were identified by 125 parks.

These energy conservation strategies are a prerequisite for sustainable design and are required to optimize the efficiency of PV systems. Because electrical loads and maintenance requirements would be reduced by implementing these strategies, the estimates of power for future PV systems greatly underestimates the true amount of energy savings and cost benefits that could be achieved.

As stated earlier, phase II survey forms were sent to each park that identified the need for larger PV projects such as remote facility power and water pumping. Phase II survey results provided information on the scale of facilities to be served by PV power so that a more complete estimate could be prepared. Cost estimates for these larger projects also include design and contract preparation costs.

The highest priority projects for the National Park Service are where power is currently being supplied by engine generator sets (usually diesel fueled). The survey results indicate a need for replacement projects at 60 locations, which would greatly improve air quality by eliminating diesel fuel emissions.

Many of the locations where diesel fuel is currently stored have experienced moderate to severe spills. Fuel spills cleanup measures have been very costly, approaching several hundred thousand dollars

per site in some cases. The use of PV systems at these sites will eliminate these groundwater and soil pollution exposures.

Reducing noise pollution in pristine areas that results from 24-hour operation of engine generators is another reason to replace diesel fuel generators with environmentally friendly and quiet PV systems.

Finally, life-cycle cost analysis indicates that in most cases, engine generated power is more costly than PV power systems and does not provide the significant environmental benefits associated with PV power.

PV powered emergency telephone at Lake Mead National Recreation Area.

IMPLEMENTATION

The cost estimates in appendix C represent program formulation estimates. Cost estimates will be further refined at the site assessment stage. The site assessment is the first activity in the pre-design step of the NPS design process and consists of

- reviewing the existing power system (if power is available at site) and assessing existing and future electrical loads
- initially evaluating renewable resources
- evaluating the potential for energy conservation
- recommending renewable energy options and costs

An example of a site assessment recently conducted at Gulf Island National Seashore by the Photovoltaic Design Assistance Center is included in appendix E. The Photovoltaic Design Assistance Center conducts these site assessments at no charge to the National Park Service. Assessments can be scheduled by contacting Hal Post at (505) 844-2154 or Mike Thomas at (505) 844-1548. Private engineering firms and PV system integrators can also provide this service on a fee basis.

If the site assessment indicates PV or other renewables are feasible, additional pre-design activities such as implementing energy conservation practices, evaluating solar and/or wind resources at the site, and field monitoring of electrical and fuel loads can take place. The remaining design steps such as prelininary design, contract

documents, construction, and post-construction evaluation are outlined in NPS-70 (Interim Release, March 1994).

PARTNERSHIPS

The list of proposed PV projects shown in appendix C is large, and the National Park Service budget is small and heavily subscribed. The National Park Service is committed to operating and developing the parks in a sustainable manner for future generations. To accomplish even a portion of the listed projects will require entering into partnerships with other government departments and agencies, national laboratories, environmental groups, private and public associations, and the PV industry.

The Department of Energy's Federal Energy Management Program has established the Federal Energy Efficiency Fund to provide cost sharing grants to federal agencies for cost-effective energy conservation, water conservation, and renewable energy projects. All units of the national park system need to explore and actively participate in this partnership opportunity. Contact John Archibald at (202) 586-1613 for further information. Several units of the national park system have already partnered with the Department of Energy and received several hundred thousand dollars for various projects.

Sandia National Laboratories and the National Renewable Energy Laboratory have both provided outstanding technical and funding assistance to the National Park Service on many renewable energy projects. Contacts at Sandia's Photovoltaic Design Assistance Center in Albuquerque, New Mexico, are Hal Post (505) 844-2154 or Mike Thomas at (505) 844-1548. Contacts at the National Renewable Energy Laboratory in Golden, Colorado, are Bob Westby at (303) 275-6021 or John Thornton at (303) 384-6469.

Electrical utilities at both the local and national level are becoming more interested in energy conservation and renewable energy power systems. Many local utilities offer rebates or other financial incentives to implement energy conservation measures. Several utilities are currently investigating the use of PV energy at several parks in lieu of power line extension or replacement. The Western Area Power

Administration is very interested in promoting the use of energy conservation and renewable energy to member utilities and their customers. Contact Peggy Plate at 1-800-472-2306 for potential partnership information and details. At the national level, the Utility PhotoVoltaic Group can provide a variety of opportunities to accelerate the use of PV power by utilities. The contact person for the Utility PhotoVoltaic Group is Bethany Wills at (202) 857-0898).